Notes ichtyologiques / *Ichthyological notes*

Capture of a pregnant female white shark, *Carcharodon carcharias* (Lamnidae) in the Gulf of Gabès (southern Tunisia, central Mediterranean) with comments on oophagy in sharks

by

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RÉSUMÉ. - Capture d'une femelle gravide de requin blanc dans le golfe de Gabès (Tunisie méridionale, Méditerranée centrale) avec des commentaires sur l'oophagie chez les requins.

Les auteurs relatent la capture par un thonier d'une femelle gravide de requin blanc dans le golfe de Gabès (Tunisie méridionale, Méditerranée centrale), le 26 février 2004. La mère portait quatre embryons en cours de développement, mesurant entre 132 et 135 cm de longueur totale et pesant entre 27,65 et 31,50 kg. Les embryons présentaient un abdomen fortement distendu sous l'effet du vitellus qui emplissait leur estomac, ce qui confirme que l'espèce est oophage. Des commentaires sur l'oophagie pendant le développement embryonnaire sont présentés en se fondant sur une revue de la littérature et plus spécialement sur des publications concernant le requin blanc, mais aussi d'autres espèces oophages telles que le requin-taupe commun, *Lamna nasus*, le requin-taupe bleu, *Isurus oxyrinchus* et le renard à gros yeux, *Alopias superciliosus*.

Key words. - Chondrichthyes - Lamnidae - *Carcharodon carcharias* - MED - Tunisia - Gulf of Gabès - Oophagy - Embryonic development.

According to Francis (1996), "Few reports exist describing pregnant female or embryonic white sharks. Most were based on limited second-hand observations and many of the accounts are inaccurate". Francis (1996) listed these reports and presented the capture of a pregnant female white shark off New Zealand. Of the seven embryos carried by the female, five were aborted and two others were discovered inside it. He obtained "one intact embryo and one embryo from which the jaws and the pectoral fins had been removed" and provided for the first time a complete and thorough description of a white shark embryo.

Uchida *et al*. (1996) reported several pregnant females caught off Japan and among them a specimen captured on 22 May 1992 off Toyo, which carried ten embryos. One embryo was lost while the fishermen towed the mother to the port, and of the nine remaining embryos eight were observed by Uchida *et al*. (1996). They were near term embryos.

Since Postel (1958), captures of *C. carcharias* were reported off the Tunisian coast. In 1992, a first pregnant female carrying two embryos was captured off Cape Bon (northeastern Tunisia) and this record was reported by Fergusson (1996, 2002). On 26 February 2004, a second pregnant female was caught off the Tunisian coast, in the Gulf of Gabès (southern Tunisia). This capture offered us the opportunity to describe the mother and the embryos, to compare the latter with those previously described in literature, and to comment on oophagy in white shark during embryonic development.

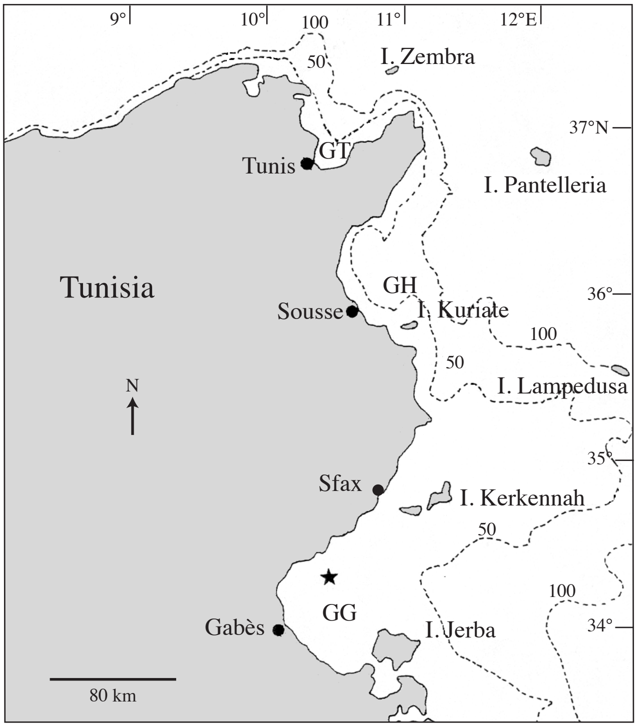

Figure 1. - Capture site (★) of the pregnant female white shark in the Gulf of Gabès (GG), Tunisia. GT: Gulf of Tunis. GH: Gulf of Hammamet. *[Site de capture (★) de la femelle gravide de requin blanc dans le golfe de Gabès (GG), Tunisie. GT : Golfe de Tunis. GH : Golfe d'Hammamet.]*

MATERIAL AND METHODS

According to fishermen, the pregnant female white shark was caught on the afternoon of February 26, 2004 in the Gulf of Gabès (34°24'N, 10°54'E), by a tunny boat in a purse seine and towed to

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Sfax Harbour, a distance of about 38 km (Fig. 1). We measured the female to the nearest cm on the deck. The embryos were removed from the uteri and carried to the "Laboratoire d'ichtyologie de l'Institut des sciences et technologies de la mer de Sfax" (Tunisia). They were measured to the nearest cm and weighed to the nearest gramme, and the liver was weighed to the nearest decigramme (Tab. I). The clasper-length of the single male embryo was measured in its inner side from the forward rim of pelvic girdle to tip of clasper, following Collenot (1969) and Capapé *et al*. (1990).

RESULTS

Description of the pregnant female

The female was 587 cm total length and its mass was estimated to be more than 2,000 kg (Fig. 2). The main morphological characteristics and teeth shape showed that it was a white shark, *C. carcharias* (see Compagno, 1984). The distended abdomen suggested that the female was pregnant.

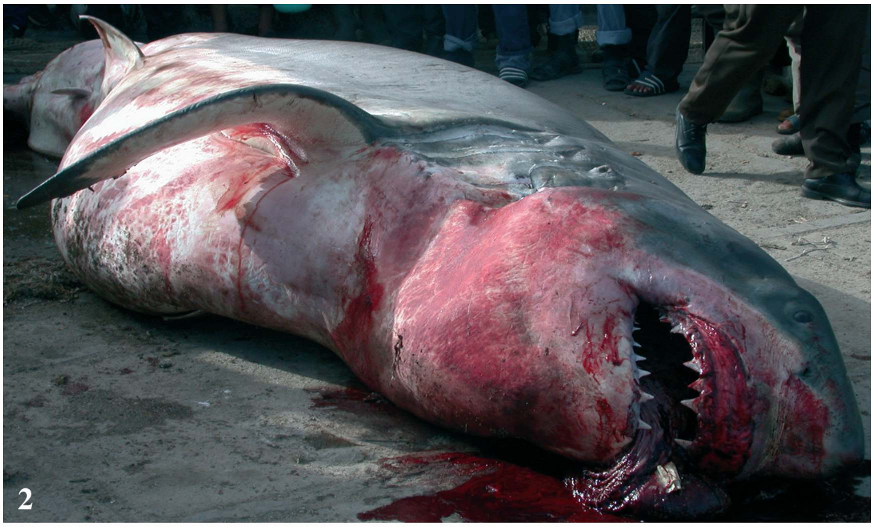
We were only able to make some measurements as follows: Snout to first dorsal fin origin: 208 cm; first dorsal fin height: 65 cm; first dorsal fin base: 66 cm; interdorsal fins space: 132 cm; anterior margin of pectoral fin length: 111 cm; pectoral fin length: 93 cm.

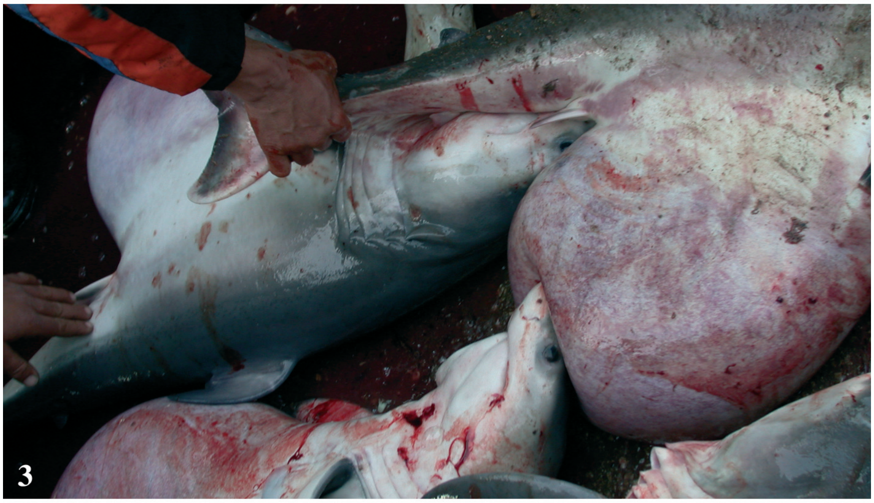
The mother was eviscerated and four developing embryos were found, one male and one female in the right uterus and two females in the left uterus (Fig. 3). The stomach was empty. We were unable to examine thoroughly the other organs because as soon as we removed the embryos, the mother was rapidly cut up and sold.

Description of the embryos

The total length of the four embryos ranged between 132 and 135 cm (mean: 133.6 ± 1.2) and their full mass between 27.65 and 31.50 kg (mean: 29.602 ± 1.693). All measurements and masses made on the embryos are included in table I. The abdomen was considerably distended by the yolk mass and no umbilical stalk or remnants of this structure was observed in each embryo. Moreover, the spiracles were incompletely shaped. The colour pattern was lighter than those of the free swimming, juveniles and adults previously observed in Tunisia (Quignard and Capapé, 1972; Bradaï, 2000). Each embryo had a first dorsal fin strongly rounded at the apex and a very lunate caudal fin.

Three embryos were opened and their stomach was full of yolk (Fig. 4). Of the four embryos, a single one was preserved in 5% buffered formalin solution and deposited in the Ichthyological Collection of the "Institut national des sciences





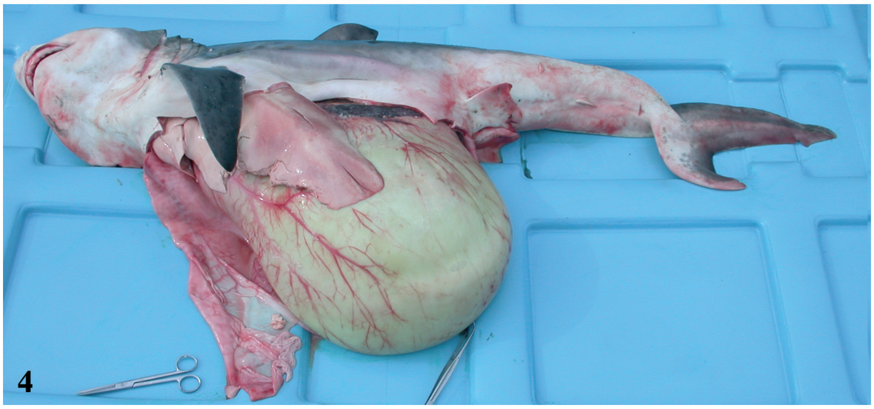


Figure 2. - Pregnant female white shark captured in the Gulf of Gabès, on 26 February 2004. *[Femelle gravide de requin blanc capturée dans le golfe de Gabès le 26 février 2004.]*

Figure 3. - Embryos removed from the uteri . *[Embryons retirés de l'utérus.]*

Figure 4. - Male embryo (ref. INSTM/LAM 01) dissected in order to show the stomach full of yolk. *[Embryon mâle (réf. INSTM/LAM 01) disséqué afin de montrer l'estomac plein de vitellus.]*

Table I. - Measurements made on the four embryos removed from the pregnant female white shark. *[Mesures prises sur les quatre embryons retirés de la femelle gravide de requin blanc.]*

Sex	Total length (cm)	Total mass (kg)	Yolk mass (kg)	Eviscerated mass (kg)	Liver mass (kg)
Male	134.0	30.40	-	-	-
Female	132.0	27.65	12.75	12.15	1.872
Female	133.5	28.86	13.33	12.99	2.160
Female	135.0	31.50	14.05	14.15	2.360

et technologies de la mer, Centre de Sfax" (Tunisia) and registered as INSTM/LAM 01. Morphometrical and proportional measurements made on this fresh embryo are given in table II.

DISCUSSION

Pregnant females with developing or near-term embryos were already caught in the Pacific Ocean and the Mediterranean (Francis, 1996, Tab. 1). In the Pacific, captures are mainly reported off Japan (Uchida *et al*., 1996; Uchida and Toda, 1996), Taiwan (Francis, 1996), Australia (Bruce, 1992) and New Zealand (Francis, 1996). Mediterranean records occurred off Egypt (Norman and Fraser, 1937, *in* Francis, 1996) and off Tunisia (Fergusson, 1996). Moreover, small free-swimming white sharks were reported in the same areas, especially in Tunisian waters where specimens less than two metres TL were collected (see Fergusson, 1996). These latter reports and the specimens described in the present article are in agreement with the Fergusson's opinion (2002) considering the central Mediterranean Sea as a nursery site for white sharks.

Some measurements made on the single embryo preserved in INSTM ichthyological collection are slightly different from those reported by Francis (1996) and Uchida *et al*. (1996). These differences concern eye diameter, first dorsal, pectoral height and trunk height, which are smaller in the Tunisian embryo, but it is the smallest specimen reported so far. These differences may be due to intraspecific variations or to the fact that embryos develop differently during gestation. Similar patterns were often reported among embryos from a same litter in viviparous sharks (Capapé *et al*., 2004). The differences in clasper length between Tunisian and Japanese embryos may relate to the use of a different method of measurement.

A literature review of pregnant female and embryonic white sharks (see Francis, 1996, Tab. I) showed that litter sizes ranged between 2 and 14; however, litter sizes above 10 require confirmation. Moreover, there does not appear to be a relationship between litter size and mother's length. The largest litter sizes, 11 and 14 (?), were found in two females having 4.00 and 4.20 m respectively, the smallest, 2, in a female 5.30 m large caught off Cape Bon, in northeastern Tunisia (Fergusson, 1996). Nevertheless, according to Fergusson (1966), Francis (1996) and Uchida *et al*. (1996), pregnant females might abort their embryos when caught. No information suggesting abortion was provided by fishermen for our Tunisian specimen. Despite their large length and mass, a high percent of yolk mass (43-45%) of the Tunisian embryos suggested that they were not near-term. It was also difficult to determine the period of embryonic development because the rate of absorption of yolk mass cannot be determined from literature or our present observations. The yolk stomach was completely reabsorbed in a 144.9 cm TL embryo, found in a pregnant female from North Cape, New Zealand (Francis, 1996, Fig. 2), and it had a healed scar on the throat. Similar patterns were observed in the Toyo embryos (Uchida *et al*., 1996). For the North Cape embryo, Francis (1996) noted: "Much of the distended abdomen was occupied by a liver weighing 4.3 kg… the liver represented 16.5 % of its total body weight". In the Tunisian embryos, the liver mass was between 6.7 and 7.5% of body mass. So, nutriment transfer from yolk to liver remains a probable hypothesis in agreement with both Gilmore (1983) and Francis's opinion (1996) who noted: "the lack of yolk in the stomach of the 143.0 cm embryo and the large liver, are consistent with suggestions that lamnoid embryos consume all intra-uterine supplies and store the energy in an enlarged liver before birth". The high yolk mass found in Tunisian embryos stomach, and the lack of yolk in the North Cape embryo stomach show that embryophagy does not occur in white sharks, in agreement with Francis's opinion (1996). Moreover, the embryo mass reported by Francis (1996, Tab. II) reached a larger TL, but a lower mass than the Tunisian embryos (present article, Tab. 1). This could also explain why in the latter, the liver mass was a lower percent of total body mass.

The Tunisian embryos had not placental attachments between them and the mother. This also agrees with Francis (1996) and Uchida *et al*. (1996). Healed scars on throats were described in near term embryos and persisted after birth according to Klimley (1991), Francis (1996) and Uchida *et al*. (1996). Francis (1996) noted that "they may represent the site of absorption of the yolk sac and its stalk". In a later study on *Lamna nasus*, Francis and Stevens (2000) concluded that the ventral scar results from splitting of subdermal muscle layers as the yolk stalk expands. Similar patterns were observed in Tunisian embryos, which exhibited a small-vascularized area, of about 4 cm^2, on the belly. In agreement with Francis (1996) and Uchida *et al*. (1996), our present observations confirm that the white shark is an aplacental viviparous species and the embryos are nourished by oophagy.

Based on large *Lamna nasus* samples, Francis and Stevens (2000) and Jensen *et al*. (2002), showed that females produced thousands of oocytes, and the longest ones reached 6-7 mm in diameter. According to Francis and Stevens (2000) and Jensen *et al*. (2002), in *L. nasus* embryonic development and growth comprise four stages. At the beginning of the first stage, the uteri contain blastodic capsules with a single fertilized ovum and nutritive capsules with unfertilized ova. Then encapsulated embryos are nourished by the yolk sac attached by a short stalk up to a size between 3.2 and 4.2 mm. During the second stage, after hatching the capsule is broken by posthatch embryos ranging between 47 and 51 mm TL and exhibiting an abdomen "slightly swollen". During the third stage, the internal yolk sac was entirely reabsorbed and the embryos increase in size. The embryos recorded by Duhamel and Ozouf-Costaz (1982) in a female *L. nasus* from Kerguelen Islands ranged between 11.6 and 12.2 cm TL, exhibited a functional dentition and were surrounded by 102 nutritive capsules. Similar patterns were described in the bigeye thresher shark, *Alopias superciliosus* by Moreno and Morón (1992), in the shortfin mako, *Isurus oxyrinchus* by Mollet *et al*. (2000) and occurred in white sharks (Francis, 1996; Uchida *et al*., 1996). During the fourth stage, the embryos were oophagous and consumed nutritive capsules. The cumulative yolk mass weighed in three Tunisian embryos was 40.130 kg, and the calculated yolk mass of the fourth embryo (# 43% of total mass) was at least 13.0 kg. The estimated total yolk mass carried by the Tunisian pregnant white shark was 53.13 kg. The maximum diameter of ripe oocytes previously reported for *C. carcharias* was 5.06 mm (Bruce, 1992). In other sharks, the mass of similar diameter oocytes did not exceed 0.5 g. Therefore, at least the yolk mass and the total mass of embryos, 118.41 kg approxi-

Table II. - Measurements and proportional measurements (% of total length) made on the male embryo removed from the pregnant female white shark (ref.: INSTM/LAMN 01). Comparison with previous proportional measurements made on embryos from other areas. *[Mesures et mesures proportionnelles (% de la longueur totale) effectuées sur l'embryon mâle retiré de la femelle gravide de requin blanc (réf. : INSTM/LAMN 01). Comparaison avec les mesures proportionnelles précédentes effectuées sur des embryons provenant d'autres sites de capture.]*

Authors	This study		Francis (1996)		Uchida *et al.* (1996)		
Total length (TL, mm)	1340		1430	1449	1350	1500	1400
Measurements	(mm)	%TL	% TL	% TL	% TL	% TL	% TL
Precaudal length	1037	77.4	76.6	78.1	-	-	-
Fork length	1148	85.6	88.1	88.1	-	-	-
Pre-first dorsal length	431	32.2	34.5	35.9	35.0	34.0	34.6
Pre-second dorsal length	851	63.5	66.5	66.8	-	-	-
Prepectoral length	304	22.8	24.5	24.2	24.6	22.7	22.9
Head length	335	25.0	24.8	26.6	-	-	-
Prebranchial space	239	17.8	19.7	20.6	20.4	17.7	18.6
Prespiracle length	138	10.3	-	11.3	-	-	-
Preoral length	64	4.8	-	6.3	-	-	-
Interdorsal space	289	21.6	21.3	22.1	21.8	21.7	22.9
Pelvic fin length	109	8.3	-	-	-	-	-
Second dorsal-caudal length	138	10.3	-	8.3			
Prepelvic length	691	51.6	54.5	55.9	53.1	53.3	55.0
Preanal length	885	66.0	69.3	68.4	-	-	-
Pelvic-anal length	141	10.5	-	9.0	-	-	-
Pelvic-caudal length	250	19.0	18.5	19.0	17.3	16.3	15.0
Anal-caudal length	97	7.2	7.8	8.6	8.3	8.9	10.0
Snout-vent length	715	53.4	55.9	57.0	-	-	-
Vent-caudal length	625	46.6	43.4	43.3	-	-	-
Prenasal length	44	3.3	3.6	3.7	3.4	3.8	3.6
Intergill length	96	7.2	6.2	6.3	-	-	-
Eye width	19	1.2	1.5	1.4	1.5	1.5	1.5
Eye height	15	1.1	1.5	1.6	-	-	-
Internasal length	49	3.4	4.0	4.1	4.0	4.0	4.0
Mouth width	130	9.7	-	10.7	7.9	9.7	8.3
First dorsal height	111	8.3	9.3	9.3	9.5	9.1	9.0
First dorsal base	146	10.9	9.6	9.9	9.5	9.7	9.4
First dorsal inner margin	24	1.8	2.7	2.5	-	-	-
First dorsal anterior margin	172	12.8	13.6	13.6	-	-	-
Second dorsal height	18	1.3	1.3	1.5	-	-	-
Second dorsal base	22	1.6	1.5	1.6	-	-	-
Second dorsal inner margin	19	1.4	1.4	2.1	-	-	-
Second dorsal anterior margin	34	2.5	2.9	2.6	-	-	-
Pectoral height	191	14.2	-	19.7	-	-	-
Pectoral inner margin	51	3.8	-	4.1	5.7	5.7	5.0
Pectoral anterior margin	256	19.1	-	22.2	-	21.9	22.1
Caudal anterior margin	319	23.8	-	-	-	-	-
Caudal terminal lobe	61	4.5	4.7	5.1	-	-	-
Second dorsal insertion-anal insertion	37	2.7	-	-	-	-	-
Second dorsal origin-anal origin	34	2.5	-	-	-	-	-
Trunk height	165	12.3	19.2	21.7	-	-	-
Caudal peduncle height	35	2.6	2.9	2.9	-	-	-
Clasper length	108	8.0	-	-	3.4	3.2	-

mately, would require more than 200,000 ova. An ovary mass of 2.0 kg was recorded in a female caught at Streaky Bay, off southern Australia (Bruce, 1992), which "was reported to contain six to seven embryos, each 30 cm in length". Uchida *et al.* (1996) noted that "the uteri of a large female white shark caught at Kin, Okinawa, in 1985 had egg capsules that were filled with yolk material. Yolk material contained in egg capsules of the left uterus weighed 9.0 kg. Unfortunately, no embryos were obtained, and these were presumed to have been aborted during capture". Uchida *et al.* (1996) noted that the ovary mass removed from the Toyo female, which contained near term embryos, was 6.75 kg. The ovary mass grew concomitantly with embryos growth. However, according to Francis (1997), a resting period occurred between pregnancies and female produce young every 2-3 years. With regard to gestation in oophagous sharks described above, it appears that from first to third stage, encapsulated embryos consume yolk only and are strictly lecithotrophic (sensu Wourms, 1977, 1981). Oophagy started at the first stage, however, the great number of oocytes required during embryonic development and the high mass embryos carcasses show that the role of the mother cannot be totally neglected. However, the possible role of matrotrophy during embryonic development cannot be defined prior to thorough histological study of white shark genital tract during gestation will be made in agreement with Hamlett *et al.* (1993).

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